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Genetic variability, character association and path analysis for anaerobic germination traits in rice (*Oryza sativa* L.)

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Abstract
Study on genetic parameters, character associations and path coefficients of 107 rice genotypes for anaerobic germination traits revealed high variability, heritability and genetic advance as per cent of mean for seedling vigour index. High heritability and genetic advance as per cent of mean was also recorded for shoot length, root length, seedling dry weight and anaerobic response index. Further, all anaerobic germination traits studied had recorded high positive association with anaerobic response index. Among these, shoot length had recorded high positive direct and indirect effects and is identified as effective selection criterion for improvement of anaerobic response index towards tolerance to anaerobic conditions during germination for use under direct seeding.

Keywords: Anaerobic germination, character association, genetic advance, heritability, path analysis, rice and variability

Introduction
Rice, one of the world's most important food crops, feeds more than half of the world's population. Rice production in the recent years is increasingly shifting from transplanting method of cultivation to direct seeding, particularly under puddled conditions, due to reduction in cost of cultivation and early maturity of the direct sown crop (Pandey and Valesco, 2002) [16]. Further, poor seedling establishment under direct seeding in standing water due to heavy rainfall or improper levelling of land, resulting in unfavorable anaerobic conditions for the rice seed, leads to poor germination and failure to develop strong and uniform seedlings. Hence, tolerance for anaerobic condition during germination is an essential trait in direct seeded rice. Therefore, development of rice cultivars tolerant to anaerobic conditions during germination coupled with early seedling vigor has been reported to be an important objective under direct-seeding (Joshi *et al.* 2013, Miro and Ismail 2013 and Vijayan *et al.* 2018) [10, 14, 24]. In this context, the present investigation was undertaken to elucidate information on variability, heritability, genetic advance as per cent of mean, character association and path coefficients for anaerobic germination traits towards formulation of successful breeding programmes aimed at the development of rice varieties tolerant to anaerobic conditions during germination.

Material and Methods
The experimental material consisted of 107 elite rice genotypes. Screening of these genotypes for tolerance to anaerobic conditions during germination was undertaken at Regional Agricultural Research Station, Maruteru during *Kharif* 2017 with pro-tray method detailed by Chaitanya (2016) [5] in completely randomized design with two replications.
The screening was undertaken with three days pre-germinated seeds at pigeon breast stage. The seeds were sown in pro-trays of (35.5×10×4.5cm) at about 1 cm soil depth and submerged in tanks by filling water upto 10 cm above the trays. Observations were recorded at 14th day of submergence. Data on number of seedlings survived after 14 days of submergence was recorded as germination percentage (%). In addition, shoot length (cm), root length (cm) and seedling dry weight (mg) were recorded for each variety in each replication. Further, seedling vigour index (Kharb *et al.*, 1994) [12] and anaerobic response index (Hsu and Tung, 2015) [9] were estimated as per the standard procedures suggested by earlier workers. The data collected was subjected to standard statistical procedures given by Panse and Sukhatme (1978) [17]. Correlation was worked out using the formulae suggested by Falconer (1964) [8].

Partitioning of the correlation coefficients into direct and indirect effects was carried out using the procedure suggested by Wright (1921) [25] and elaborated by Dewey and Lu (1959) [7]. Characterization of path coefficients was carried out as suggested by Lenka and Mishra (1973) [13].

Results and Discussion

The results on analysis of variance (ANOVA) for anaerobic germination traits revealed highly significant mean squares due to genotypes for all traits studied, indicating the existence of sufficient variation among the genotypes. The results on mean, range, phenotypic coefficient variation (PCV), genotypic coefficient variation (GCV), heritability and genetic advance as per cent of mean for the anaerobic germination traits are furnished in Table 1. A perusal of these results revealed maximum range of varability for the trait germination percentage (28.81-85.11) while minimum range (0.60-4.85) was recorded for anaerobic response index. Higher PCV, compared to GCV were recorded for all the traits studied in the present investigation, indicating the influence of environment. Similar findings were reported earlier by Tiwari *et al.* (2019) [22]. However, high estimates (>20%) of PCV were recorded shoot length (20.44), root length (22.14) and seedling vigour index (33.85). High GCV (32.77) was also recorded for seedling vigour index. Similar results were reported by Barik *et al.* (2019) [2]. However shoot length (19.64), root length (19.49), seedling dry weight (16.49) and anaerobic response index (17.33) had recorded moderate (10-20%) GCV. The findings are in conformity with the reports of Ravikanth *et al.* (2018) [19]. In contrast, low GCV ((9.09) coupled with moderate PCV (11.42) was recorded for germination percent. Similar results were reported earlier by Barik *et al.* (2019) [2].

High estimates of heritability (> 60%) were recorded for germination percentage, shoot length, root length, seedling dry weight, seedling vigour index and anaerobic response index. These results are in broad agreement with the findings of Bordoloi and Sarma (2018) [3]. A perusal of the results on genetic advance as percent of mean revealed high values (>20%) for shoot length, root length, seedling dry weight, seedling vigour index and anaerobic response index. The results are in accordance with the reports of Ravikanth *et al.* (2018) [19]. Further, moderate estimates (10-20%) of genetic advance as per cent of mean was observed for germination percentage. The results are in agreement with Singh *et al.* (2018) [20].

High heritability coupled with high genetic advance as per cent of mean was recorded for shoot length, root length, seedling dry weight, seedling vigour index and anaerobic response index indicating that heritability observed was due to additive gene effects and therefore selection would be effective for these traits. However, germination percentage had recorded high heritability coupled with moderate genetic advance as per cent of mean indicating the role of additive and non additive gene effects for control of this character. Further, information on genetic variation along with heritability and genetic advance estimates has been reported to give a better idea about the efficiency of selection (Burton, 1952) [4]. In the present study, high GCV and PCV coupled with high heritability and high genetic advance as per cent of mean was observed for seedling vigour indicating the pre-ponderance of additive gene action and therefore scope for improvement of the trait through selection.

Character associations between different anaerobic germination traits studied in the present investigation are presented in Table 2. A perusal of these results revealed positive and significant association of anaerobic response index with germination percentage, shoot length, root length, seedling dry weight and seedling vigour index indicating an increase in anaerobic response index was observed with an increase in these characters. Studies on inter-character associations for anaerobic germination traits also revealed significant and positive association of germination percentage with shoot length (Bordoloi and Sarma, 2018) [3], root length (Patil *et al.* 2014) [18], seedling dry weight (Chaitanya *et al.* 2018) [6] and seedling vigour index (Umarani *et al.* (2019) [23]; shoot length with root length (Bordoloi and Sarma, 2018) [3], seedling dry weight (Chaitanya *et al.* 2018) [6] and seedling vigour index (Addanki *et al.* 2018) [1]; root length with seedling dry weight (Jan *et al.* 2019) [15] and seedling vigour index (Sujay, 2007) [21]; Seedling dry weight with seedling vigour index (Kavitha *et al.* 2019) [11] indicating a scope for simultaneous improvement of these traits through selection.

Path co-efficient analysis provides an effective means of finding out the direct and indirect causes of association and presents a critical examination of the specific forces acting to produce a given correlation and also measures the relative importance of each causal factor. Hence, the study of direct and indirect effects of anaerobic germination traits on anaerobic response index was undertaken in the present investigation and the results obtained are presented in Table 3 and Fig. 1. A perusal of these results on path coefficients for anaerobic germination traits revealed high residual effect for (0.4856) path coefficients indicating that variables studied in the present investigation explained only about 51.44 per cent of variability for anaerobic response index and therefore other attributes besides the characters studied are contributing for anaerobic response index.

Table 1: Genetic parameters for anaerobic germination traits in rice

S. No	Character	Mean	Range		PCV (%)	GCV (%)	Heritability (broad sense) (%)	Genetic advance as per cent of mean
			Min	Max				
1.	Germination percentage	55.52	29.88	83.51	11.42	9.09	63.00	14.91
2.	Shoot length	16.42	9.75	25.65	20.44	19.64	92.00	38.86
3.	Root length	4.04	0.35	6.65	22.14	19.49	78.00	35.35
4.	Seedling dry weight	21.48	13.75	32.90	17.44	16.49	89.00	32.13
5.	Seedling Vigour index	11.85	3.65	27.02	33.85	32.77	94.00	65.33
7.	Anaerobic Response Index	2.12	0.60	4.85	19.33	17.33	77.00	31.36

Table 2: Correlation matrix for anaerobic germination traits (pro-tray method) in rice

Character	Shoot length (cm)	Root length (cm)	Seedling dry weight (mg)	Seedling vigour index	Anaerobic response index
Germination	0.8074**	0.8826**	0.7456**	0.9630**	0.7944**
Shoot length		0.6905**	0.7201**	0.9224**	0.8481**
Root length			0.5725**	0.8562**	0.6861**
Seedling dry weight				0.7687**	0.7245**
Seedling vigour index					0.8540**

*Significant at 5% level, **Significant at 1% level

Table 3: Direct and indirect effects of anaerobic germination traits on anaerobic response index in rice

Character	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling dry weight (mg)	Seedling vigour index	Anaerobic response index
Germination per cent	0.0958	0.3781	0.0313	0.1191	0.1701	0.7944**
Shoot length	0.0774	0.4683	0.0245	0.1150	0.1629	0.8481**
Root length	0.0846	0.3234	0.0355	0.0914	0.1512	0.6861**
Seedling dry weight	0.0715	0.3372	0.0203	0.1597	0.1358	0.7245**
Seedling vigour index	0.0923	0.4320	0.0304	0.1228	0.1766	0.8540**

Diagonal values indicate direct effect
Residual effect = 0.4856
*Significant at 5% level
** Significant at 1% level

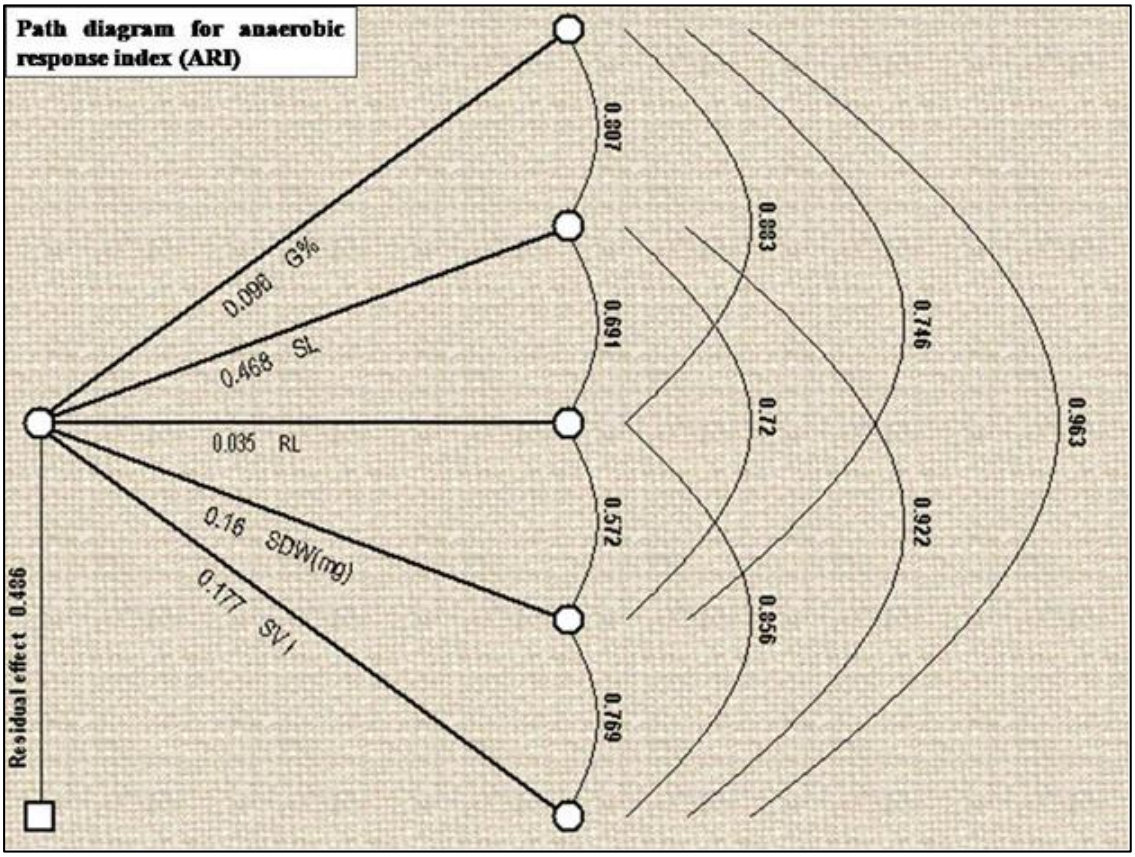

Fig. 1: Path diagram showing direct and indirect effects of anaerobic germination traits on anaerobic response index in rice

A detailed analysis of the direct and indirect effects also revealed high (>0.3) positive direct effect for shoot length (0.4683), in addition to significant and positive association with anaerobic response index. High direct effects of the trait therefore appear to be the main factor for its association with anaerobic response index. The other traits, namely germination per cent, root length, seedling dry weight and seedling vigour index had also recorded correlation with ARI mainly due to indirect effect via shoot length. Hence, shoot length should be considered as an important selection criterion in anaerobic germination tolerance improvement programmes and direct selection for this trait is recommended for improvement of anaerobic response index.

Conclusion

Results of the present investigation indicated a scope for improvement of anaerobic response index through selection for shoot length in view of its high heritability and genetic advance as percent of mean, in addition to high positive association coupled with high direct and indirect effects on anaerobic response index.

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